WO 00/30224

4/PRTS

09/831995
L 698 181385
PCT/AU99/01019
JC18 Rec'd PCT/PTO 1 6 MAY 2001

REDUCTION OF PULSATIONS IN DFB LASERS

Field of the Invention

The present invention relates to a method of reducing intensity pulsation in distributed feedback (DFB) lasers, e.g. in DFB fibre lasers.

Background of the Invention

The utilisation of optical fibre networks in telecommunications is becoming more and more prevalent due to their high bandwidth capabilities. Further, with the recent introduction of erbium doped fibre amplifiers (EDFA) wavelength division multiplexing (WDM) systems are being introduced so as to multiplex multiple channels. The increase in WDM density places more stringent requirements on the principles of operation. This requires laser transmitters with accurate wavelength selection and high wavelength stability, in addition to low power output fluctuations.

Fibre lasers such as Er-doped DFB fibre lasers in general are ideally suitable as they are fully fibre-compatible allowing for very low coupling losses. The potential of DFB fibre lasers as low noise, narrow linewidth sources for WDM systems has been demonstrated recently in digital transmission tests. Further, with a passive temperature-compensated package, the wavelength stability of DFB fibre lasers could be set better than 1 GHz within -20/+80°C temperature range.

However, due to self-pulsation in Er-doped DFB lasers, there exist power fluctuations in the output of such lasers. The origin of self-pulsations is related to ion clustering at high erbium concentrations [Sanchez et. al. Phys. Rev. A, 48(3), 2220-2229]. The clusters act as saturable absorbers with switching time much shorter than the population inversion recovery time and can eventually result in spiking behaviour of the laser.

Reducing the erbium concentration whilst still providing enough gain in a short cavity DFB fibre laser can be achieved by Yb co-doping [Kringlebotn et. al. IEEE

- 2 -

Photon. Technology Letters 5(10), 1162-1164 (1993)] which
increases the pumping efficiency. However, where it is
desired to arrange several DFB fibre lasers in series, this
method can have the disadvantage that the Yb dopant absorbs
a significant portion of the pumping energy, and therefore
separate pumping sources would typically be required.

Stabilisation of the laser against self-
pulsations can also be accomplished by resonant pumping
[Loh et al, Optics Letters 21(18), 1475-1477 (1996)] or co-
pumping [Loh et. al. Optics Letters, 22(15), 1174-1176
(1997)] directly into the metastable Er-ion state, damping
down the oscillations of the population inversion.
However, this approach has the disadvantage that the
pumping wavelength would lie close to the signal
wavelength. Presently, sources for wavelengths close to
commonly used signal wavelengths of around 1480 nm are
quite expensive.

Summary of the Invention

The present invention provides a method of reducing fluctuations in the output
power of a distributed feedback laser arrangement incorporating a waveguide structure
having a distributed feedback region, a signal amplification region for amplifying an
output of the distributed feedback region and a saturable absorption region, the method
comprising using light from the distributed feedback region to induce a saturable
absorption grating in the saturable absorption region.

The method may be effected in a laser arrangement wherein the saturable
absorption region is provided at one end of said signal amplification region.

The method may be effected in a laser arrangement wherein said saturable
absorption region forms part of said signal amplification portion.

The method may be effected in a laser arrangement wherein said signal
amplification region is in a feedback loop with said distributed feedback region.

Said feedback loop may be formed by coupling a portion of an output of said
signal amplification region to said

- 3 -

distributed feedback region.

Said distributed feedback laser region may be formed from Erbium doped fibre.

Said signal amplification region may be formed from Erbium doped fibre.

Said saturable absorption region may be formed from Erbium doped fibre.

The feedback loop may provide a phase-conjugated feedback signal to the output of the distributed feedback region.

The feedback signal may provide resonant pumping as well as saturate gain in the distributed-feedback region to the threshold value.

The method may be effected in a laser arrangement wherein a number of said distributed feedback regions are connected in series.

One signal amplification region and one saturable absorption region and one feedback loop may be shared between said distributed feedback regions to form the arrangement.

The method may be effected in a laser arrangement wherein the distributed feedback region comprises a Bragg grating structure.

The Bragg grating structure may comprise a chirped Bragg grating.

The Bragg grating structure may comprise a sampled Bragg grating.

The Bragg grating structure may comprise a phase shifted Bragg grating.

The grating structure may comprise an apodised grating.

The method may be effected in a laser arrangement wherein the waveguide structure comprises a planar waveguide.

The distributed feedback region may be in the form of a planar waveguide.

The signal amplifying region may be in the form of a planar waveguide.

The saturable absorption region may be in the form of a planar waveguide.

Brief Description of the Drawings

Notwithstanding any other forms which may fall within the scope of the present invention, preferred forms of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a schematic illustration of the arrangement of the preferred embodiment;

Fig. 2 illustrates the dynamics of the laser output with and without feedback;

Fig. 3 illustrates power distribution along the power amplifier at 47mW of launched 980nm pump power.

Fig. 4 illustrates the laser line width measured with and without feedback.

Description of Preferred and Other Embodiments

Turning initially to Fig. 1, there is illustrated the preferred arrangement 1 in which a 6cm long DFB structure 2 was written in an erbium doped fibre. The DFB was pumped by a 980nm pump 3. The DFB structure 2 absorbed only approximately 20% of the launched pump power producing approximately 0.5mW of output. The rest of the pump power was used to pump a section of low concentration Er-doped fibre 4. The fibre was available commercially as EDF-2 from Redfern Fibres of Australian Technology Park, Redfern, NSW, Australia. The EDF section 4 acts as a power amplifier to scale the laser output of DFB structure 2 to approximately 10mW.

The DFB master oscillator 2 was not isolated from the amplifier section 4 and its performance was affected by an intentionally induced feedback provided by a low reflectivity loop mirror 5 which was based on a coupler 6 which provided a 3% output coupler in ratio. The feedback provides a counter propagating wave in the power amplifier.

The technique of suppressing output oscillations relies on the process of saturable absorption at the end of the amplifier section 4.

Without the feedback from the mirror 5 the laser exhibited self-pulsations (curve 100 in Figure 2). With the mirror 5, however, it operates in cw mode (see curve 110 in Figure 2). As illustrated in Figure 3, a long

5   section of the power amplifier 4 is under-pumped, i.e. it produces loss rather than gain. Accordingly, in the preferred embodiment an absorption grating can be induced in that section of the power amplifier by the interference pattern of the counter-propagating waves due to the

10   saturable nature of absorption in Er-doped fibres. It will be appreciated, however, that alternatively a further length of Er-doped fibre or saturable absorption region in another form could be provided.

The process of four-wave mixing ensures that the

15   feedback signal is phase-conjugated to the DFB output, eliminating the effect of environmental perturbations on the phase of the feedback signal. The four waves involved in the four-wave mixing are I) a first outgoing wave from the DFB, which interferes with II) a reflected wave from

20   the mirror 5, and III) a further outgoing wave from the DFB, with IV) the resultant scattered wave. The amplified feedback signal provides resonant pumping as well as saturates the gain of the DFB to the threshold value, damping down relaxation oscillations in the population

25   inversion. Additionally, the DFB is injection locked to the feedback signal which is always within the locking range of the laser.

Alternatively, the laser can be viewed as a four-mirror cavity, which can be described using the approach

30   suggested in [Horowitz, R. Daisy, and B. Fischer, *Opt. Lett.*, 21(4), 299-301 (1996)]. In the present case the filtering effect is primarily related to the phase discrimination properties of the absorption grating which discriminates the modulation sidebands (Fig. 4) with

35   respect to the carrier frequency since they are not necessarily correlated in phase.

It would be appreciated by a person skilled in

the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiment without departing from the spirit or scope of the invention as broadly described. The present embodiment is, therefore, to be considered in all respects to be illustrative and not restrictive.